MASTER OF SCIENCE
IN
PHYSICAL OCEANOGRAPHY

AN ANALYSIS OF THE EFFECTS OF ENERGY SPREADING LOSS AND TRANSMISSION LOSS ON LOW FREQUENCY ACTIVE SONAR OPERATIONS IN SHALLOW WATER

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Energy Spreading Loss (ESL) is qualitatively defined as the reduction in peak power level due to energy spreading of a transmitted acoustic pulse in time. An analysis of the impact of bathymetric geometry and sediment type on ESL and TL associated with the Low Frequency Active/Compact Low Frequency Active (LFA/CLFA) sonar operations was conducted utilizing the FEPE, FEPE_SYN and EXT_TD programs to model the time spreading of the acoustic pulse due to multipath propagation in shallow water. Both a Blackman windowed pulse and a Continuous Wave (CW) pulse were used in this analysis. The Blackman pulse had a center frequency of 244 Hz with a bandwidth of 24 Hz. The CW pulse had a center frequency of 244 Hz with a bandwidth of 0.0625 Hz. Model inputs were a geoacoustic description of the Tanner flank region off the coast of San Diego and a typical late summer sound speed profile taken from the MOODS database. ESL and TL's impact on low frequency active sonar operations was determined as a function of bathymetry, sediment type, sound speed profile, and pulse length. The results showed that ESL is inversely related to pulse duration and at low frequencies is relatively uninfluenced by sediment type. When pulse lengths were reduced to less than 1 second, ESL became appreciable (>6 dB one way) and was an important segment of the active sonar equation. TL was found to be the dominating factor in LFA/CLFA operations for pulse lengths greater than 1 second and was greatly influenced by sediment type and sound speed profile.

ADRIATIC SEA CURRENT OBSERVATIONS USING ACOUSTIC DOPPLER CURRENT PROFILER (ADCP) MEASUREMENTS

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The measurement of absolute subtidal currents throughout the water column is a complex task, especially with the presence of strong high frequency events that continuously perturb the mean flow patterns. Shipboard Acoustic Doppler Current Profiler (ADCP) instruments provide a quick, easy way to measure currents relative to an underway vessel. The goal of this work is to analyze and process six shipboard ADCP data sets to study the absolute mean subtidal Adriatic Sea currents. Horizontal charts and vertical sections are presented for the absolute currents. A comparison with historical data, concurrent drifter and moored current meter observations confirms the validity of the ADCP measurements. These current measurements update regional oceanic models, refine the knowledge of basin circulation patterns, and improve our knowledge on how this circulation affects the remainder of the Mediterranean Sea.

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DEVELOPMENT OF A LOW FREQUENCY AMBIENT NOISE
STORM MODEL FOR THE ARCTIC OCEAN
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The development of an ambient noise model for use in ice-covered Arctic waters is the primary goal of this research. The generation of ambient noise is considered to originate from large scale deformation of the ice cover (pressure ridge formation) which is caused on a synoptic scale by convergence of the ice cover due to wind stress/speed associated with the passage of Arctic storms.

The Arctic Storm Noise Model (ASNM) has been developed as a dynamic model to predict the occurrence of extreme noise events. The emphasis is on accurately predicting the large increases or decreases in ambient noise, which observations have shown to be in the order of 20 to 30 dB over a matter of hours.

ASNM was adapted from the Ambient Noise Directional Estimation System (ANDES) for use under the Arctic pack ice. ASNM predictions are compared quantitatively to noise measurements made by ice-mounted drifting buoys in the Arctic basin during the early 1990's. Results showed that for extreme events (<5th or >95th percentile) ASNM is accurate in predicting both the level of ambient noise and the large increases in the noise record.

Due to the encouraging results further improvements are recommended to increase the robustness of the model for potential tactical use by submarine units operating under the Arctic pack ice.

TOWED ARRAY PERFORMANCE IN THE LITTORAL
WATERS OF NORTHERN AUSTRALIA
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The goal of this research was to investigate the performance of low frequency passive sonars in the Arafura Sea. Sound speed profiles representative of the wet and dry monsoon seasons and geoacoustic data were inputted into a finite element primitive equation transmission loss model to model the expected propagation at three frequencies, 10, 50, and 300 Hz. Initial detection ranges for several source/receiver depth combinations and geoacoustic areas (deep/shallow water) were compared and evaluated. Results demonstrate that low frequency (~10 Hz) detection ranges suffer due to cutoff frequency problems and to surface–decoupling loss. Propagation in deep water has the added disadvantage of excessive loss of signal power due to spherical spreading considerations. Conversely, higher frequencies (300 Hz) provided extended detection ranges in shallow water due to trapping of energy within the entire 50 m to 100 m water column.

Additionally, investigation into advantages to be gained through advanced signal processing techniques shows that improvements of the order of 10 to 15 dB of detection gain are possible through the utilization of inverse beamforming.

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MODELING THE PERFORMANCE OF THE PT SUR HYDROPHONE ARRAY IN LOCALIZING BLUE WHALES

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The acoustic activity of the blue whale is widely documented yet poorly understood. Hypotheses for its vocalizations range from communication, bathymetric echolocation, and echolocation of zooplankton masses. Although extensive documentation of frequency structure and duration exists, a long-term monitoring of where and when the vocalizations are being made must be accomplished to test the validity of these theories.

The Naval Postgraduate School (NPS) Ocean Acoustic Observatory (OAO), which operates a former Sound Surveillance System (SOSUS) at Pt Sur, presents itself as a potentially valuable tool in the detection and localization of Pacific blue whales. By estimating the transmission loss as a function of bearing, range, and frequency and synthesizing the ambiguity surface of various model-data linear correlation localization algorithms, an assessment of the array's expected performance for this purpose was obtained. Important findings of this modeling study include estimated maximum detection ranges are longer than 500 kilometers both seaward and along the continental slope due to array beamforming gains and matched field localization algorithms are accurate and robust in the presence of white noise. The application of the results of this study towards the development of a "real-time," large-area blue whale localization and tracking algorithm is promising.

COMPARISON OF LOS ALAMOS NATIONAL LABORATORY (LANL) PARALLEL OCEAN PROGRAM (POP) MODEL FIELDS WITH PACIFIC SURFACE DRIFTER MEASUREMENTS

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Model fields from the Los Alamos National Laboratory (LANL) Parallel Ocean Program (POP) 1/6 degree global circulation model are compared to measurements from over 1300 satellite-tracked surface drifters that were deployed in the tropical Pacific (20N to 20S), between 1979 and 1994, during the TOGA Pan-Pacific Current Study. Geographic averages of 5-day averaged drifter velocity estimates for 2-deg. latitude x 8-deg. longitude bins are compared to similarly binned 3-day model snapshots from September 1992 to October 1994. Eulerian comparisons of the model mean velocities and their observed counterparts show that the model u mean is slightly higher in the equatorial region, while the model v mean is 50% greater in this region. Model SST mean values are 20% less than observed values in the eastern equatorial Pacific. Model variability is about 20% less than the observed quantity in equatorial regions, and 50% less poleward of l0S and 10N. Both model and observed velocity and SST covariance fields imply a net heat convergence toward the equator with the largest values in the region of instability waves north of the equator. Model velocity fields are used to produce simulated Lagrangian trajectories for uniform and nonuniform deployment strategies. Autocorrelation, time and length scales, diffusivity, and polarization are calculated and ensemble-averaged by 5 deg. latitude bands for comparison with drifter-based Lagrangian statistics. Time and length scales are too long and diffusivities too low compared to observations, but data sampling in the simulated fields was biased by trajectories that overlap current regimes. These differences, in both Eulerian and Lagrangian comparisons, may be related to the lack of a surface mixed layer, inadequate representation of wind forcing, still too coarse grid resolution, and deficiencies in simulating the mean structure of the density field in the model. They are also partly related to lack of weighted averages to account for non-uniform drifter sampling.

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MONITORING TEMPERATURE VARIABILITY ALONG THE CALIFORNIA COAST USING ACOUSTIC TOMOGRAPHY

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The electronic emissions of a low-frequency sound source placed by the Acoustic Thermometry of Ocean Climate (ATOC) project on Pioneer Seamount were monitored by a bottom-lying receiver on Sur Ridge from April 1996 to February 1997. The processed signals show a stable arrival pattern that was repeated in all the transmissions during the 11 months. Using the processed data, a tomographic analysis to study the coastal ocean variability along this California transmission path was conducted. Systematically, the analysis involved forward acoustic modeling of the arrival structure using ray theory, associating the observed arrivals with the modeled arrivals, extracting the travel times of the arrivals, inverting the travel times for temporal and spatial temperature changes, and interpreting the observed temperature variations. In particular, the tomographic estimate was compared to the temperature and wind measurements from an in situ mooring deployed by the Monterey Bay Aquarium Research Institution (MBARI). The comparison showed that the tomographic estimate is of high quality and that the observed temperature variations were linked to coastal upwelling and downwelling events. The data, methods, and result, demonstrating fully the feasibility of using tomography to study coastal temperature variability in central California on a long-term basis, are presented.

A STOCHASTIC MODEL FOR SHOALING WAVES

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Boussinesq-type equations for weakly nonlinear, weakly dispersive waves have been used extensively to model wave shoaling on beaches. Deterministic Boussinesq models cast in the form of coupled evolution equations for the amplitudes and phases of discrete Fourier modes (Freilich and Guza, 1984) describe the shoaling process accurately for arbitrary incident wave conditions, but are numerically cumbersome for predicting the shoaling evolution of continuous spectra of natural wind-generated waves. Here an alternative stochastic formulation of a Boussinesq model (Herbers and Burton, 1996, based on the closure hypothesis that phase coupling between quartets of wave components is weak) is implemented that predicts the evolution of a continuous frequency spectrum and bispectrum of waves normally incident on a gently sloping beach with straight and parallel depth contours. The general characteristics of the model are examined with numerical simulations for a wide range of incident wave conditions and bottom profiles. Stochastic and deterministic Boussinesq model predictions are compared to field observations from a cross-shore transect of bottom pressure sensors deployed on a barred beach near Duck, NC, during the recent DUCK94 Experiment. Predictions of the two models are similar and describe accurately the observed nonlinear shoaling transformation of wave spectra.

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VARIATIONS IN COASTAL CIRCULATION OFF CENTRAL CALIFORNIA, SPRING-SUMMER 1993, 1994, 1995

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In situ measurements of hydrographic, wind, and Acoustic Doppler Current Profiler (ADCP) data, along with satellite imagery, were collected off central California during the upwelling season of three successive years, 1993, 1994, and 1995. The survey was conducted three times in the late spring of each year within 75 km of the coastline from Point Reyes south to Cypress Point, along a region of irregular coastline and bathymetry. The upwelling circulation was found to be distinct from the California Current System and unlike circulation defined in recent conceptual models for this region. Persistent or recurring circulation features were observed throughout the upwelling season that acted as dynamic boundaries to this system. A varied response by upwelling centers in this region to a fairly uniform wind field was also observed. Water upwelled within this system is considered to recirculate and mix, retained within the system for a relatively long period of time. This long retention period of upwelled water is thought to promote the high productivity associated with coastal upwelling. The circulation patterns found in this region, and the dynamic boundaries to the principal equatorward current may represent upwelling circulation at multiple locations in this and in other eastern boundary current systems, inshore of the principal equatorward current.

LAGRANGIAN MEASUREMENTS OF EDDY CHARACTERISTICS IN THE CALIFORNIA CURRENT SYSTEM

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During the Eastern Boundary Current program in 1993, 96 Argos-tracked surface drifters, drogued to 15 m depth, and satellite thermal imagery were used to provide a description of the mesoscale features in the California Current System off the northern California coast. The drifter movements and satellite images revealed a highly energetic series of filaments and eddies that dominated the summer flow field off the coast, similar to those noted in the earlier CODE, OPTOMA, and CTZ studies. Winter mesoscale activity in the region was less energetic, with the principal feature being the poleward-flowing Davidson Current.

Translation rates for mesoscale eddies were deduced from drifter trajectories in the summer period. Translation rates, vorticity, divergence, and eddy center positions were also estimated for a cyclone and anticylone sampled in July and September, respectively, by constraining observed drifter velocities to a linear Taylor expansion in the least square sense. Translation rates from this technique were similar to those observed from previous shipboard surveys and drifter motions. Using observations over 7 (12) days, the cyclonic (anticyclonic) eddy was determined to have a translation rate of 3.7 (4.2) cm/s to the southwest. The least square technique, applied to shorter time periods, however, provided unreliable estimates of eddy properties when drifters were not evenly distributed around the eddy.

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**MODELING STUDIES OF WIND AND THERMOHALINE FORCING ON
THE CALIFORNIA CURRENT SYSTEM**
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A high-resolution, multi-level, primitive equation model is initialized with climatological data to study the combined effects of wind and thermohaline forcing on the ocean circulation of the California Current System (CCS). The ocean circulation is generated by the model using a combination of climatological wind stress and thermohaline forcing. In the first experiment, the effects of thermohaline forcing alone are evaluated, in the second experiment, previously conducted, the effects of wind forcing are isolated, while in the third experiment, the combined effects of wind and thermohaline forcing are looked at. The results from the combined experiment show that even though the effects of wind forcing dominate the CCS, the additional effects of the thermohaline forcing results in the following: the seasonal development of a poleward surface current and an equatorward undercurrent in the poleward end of the model region; an onshore geostrophic component, which results in a temperature front and stronger surface and subsurface currents between Cape Mendocino and Point Arena; and a region of maximum eddy kinetic energy inshore of ~125°W between Cape Mendocino and Point Arena, associated with the temperature front. These model simulations are qualitatively similar to recent hydrographic, altimetric, drifter, and moored observations of the CCS.